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CONGENITAL KIDNEY AND URINARY TRACT ANOMALIES IN CHILDREN: EARLY DETECTION AND CLINICAL MANAGEMENT

Sobirjonov Javoxirbek Solijon o‘g‘li
Fergana Premium Medical Clinic Pediatric Urologist

Abstract
Congenital anomalies of the kidney and urinary tract (CAKUT) account for 30-50% of pediatric end-stage renal disease and remain underdiagnosed in primary care settings. This prospective-retrospective study enrolled 247 children aged 0-14 years over five years. Prenatal detection was achieved in 63.2% of cases. Early intervention reduced surgical complication rates by 38.8% and significantly preserved long-term differential renal function.

Keywords:Hydronephrosis, vesicoureteral reflux, cakut, pyelectasis, pyelonephritis; nephrosonography, scintigraphy, urodynamics, obstructive uropathy, renal dysplasia, cystography, reflux nephropathy.

Introduction

Congenital anomalies of the kidney and urinary tract (CAKUT) affect 3-6 per 1,000 live births and collectively represent the leading structural cause of chronic kidney disease in children under 16 years, accounting for 30-50% of all pediatric cases requiring renal replacement therapy. Hydronephrosis, vesicoureteral reflux, and ureteropelvic junction obstruction constitute the three most frequently encountered subgroups, yet their clinical trajectories diverge considerably depending on the timing of diagnosis. Registry data from European pediatric nephrology networks document that approximately 25% of affected children reach a clinically significant reduction in glomerular filtration rate before a formal diagnosis is established. The diagnostic burden on tertiary referral centers is amplified by the heterogeneity of phenotypic expression, which ranges from sonographically overt collecting system dilatation to subclinical parenchymal dysplasia detectable only through radionuclide functional assessment.

Literature Review

Systematic evaluation of the prior literature reveals methodological divergence that complicates cross-study comparisons. Papayan and Savenkova (2008) demonstrated that postnatal ultrasound performed within 72 hours reclassified 41% of prenatally suspected hydronephrosis cases, attributing this to transient neonatal physiological oliguria rather than genuine resolution. Ignatova and Veltishchev (1989) established a mechanistic link between the first febrile urinary tract infection and the onset of cortical scarring in reflux nephropathy, providing the clinical rationale for antibiotic prophylaxis in high-grade VUR. Shamsiev and Atakulov (2003) reported bilateral obstructive uropathy in 22% of a Central Asian pediatric surgical cohort, substantially exceeding Western prevalence estimates and underscoring region-specific epidemiological patterns. Lopatkin and

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Pugachev (1986) advocated non-operative surveillance for SFU grades I-II obstruction, a position subsequently qualified by Dlin and Osmanov (2012), who showed that deferred pyeloplasty beyond 18 months correlates with inferior postoperative differential function recovery on DMSA scintigraphy-a finding that directly informs current operative threshold criteria.

Methodology

This investigation employed a combined prospective-retrospective design carried out at the Department of Pediatric Urology and Nephrology of a tertiary referral hospital in Uzbekistan between January 2018 and December 2022. Ethical approval was granted by the Institutional Review Board (Protocol No. 14/2018). Written informed consent was obtained from parents or legal guardians for all prospective participants; retrospective data retrieval was conducted under a formally approved waiver of consent in compliance with institutional regulations. The study cohort comprised 247 children aged 0 to 14 years, with a mean age of 3.4 ± 2.7 years and a median of 2.1 years. Males accounted for 158 patients (64.0%) and females for 89 (36.0%), a distribution consistent with the established male predominance of obstructive uropathies and posterior urethral valves. Age stratification yielded five subgroups: neonates 0-28 days (n = 43; 17.4%), infants 1-12 months (n = 78; 31.6%), toddlers 1-3 years (n = 61; 24.7%), preschool children 3-6 years (n = 38; 15.4%), and school-age children 6-14 years (n = 27; 10.9%). Inclusion required: (1) confirmed CAKUT diagnosis via at least two independent imaging modalities; (2) available antenatal records or postnatal imaging initiated within the first six months of life; and (3) minimum follow-up of 24 months. Exclusion criteria encompassed syndromic renal anomalies (including VACTERL association), confirmed chromosomal abnormalities with renal involvement, acquired obstructive lesions attributable to extrinsic neoplastic compression, and incomplete medical documentation.

Diagnostic evaluation followed a stepwise protocol. Prenatal renal pelvic anteroposterior diameter (APD) ≥ 5 mm at 20 weeks' gestation or ≥ 7 mm at or beyond 28 weeks constituted the threshold for mandatory postnatal workup. Postnatal renal ultrasound was performed within 72 hours of birth and repeated at 4-6 weeks to account for the physiological dehydration effect on collecting system caliber. Voiding cystourethrography (VCUG) was indicated when postnatal APD exceeded 10 mm or when urinary tract infection was bacteriologically confirmed at a colony count of ≥ 10^5 CFU/mL. Vesicoureteral reflux was graded according to the International Reflux Study Classification (grades I-V). DMSA scintigraphy was performed in 131 patients with VUR grades III-V or recurrent febrile episodes to quantify differential renal function and identify cortical defects. MAG3 diuretic renography was applied in 89 patients to characterize drainage kinetics at the ureteropelvic junction; obstruction was defined as T½ exceeding 20 minutes following intravenous furosemide at 0.5 mg/kg. Biochemical assessment included serum creatinine, cystatin C, and urinary beta-2-microglobulin at baseline and at 12-month intervals. Glomerular filtration rate was estimated using the Schwartz formula. Statistical analysis was performed in SPSS v. 26.0 (IBM Corp.). Continuous variables were assessed by independent-samples t-test or Mann-Whitney U test depending on normality (Shapiro-Wilk threshold $p < 0.05$). Categorical variables were analysed using Pearson's chi-square or Fisher's exact test. Kaplan-Meier curves modelled time to surgical intervention with log-rank group comparisons. Statistical significance was set at $p < 0.05$ throughout.

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Results

Of 247 enrolled patients, 156 (63.2%) received a prenatal diagnosis established during routine second- or third-trimester ultrasonography. The remaining 91 (36.8%) were identified postnatally through symptomatic presentation: recurrent urinary tract infection in 48 patients (52.7%), palpable abdominal mass in 13 (14.3%), and incidental imaging findings in 30 (33.0%). Five principal diagnostic subgroups were identified: ureteropelvic junction obstruction (UPJO) in 89 patients (36.0%), vesicoureteral reflux (VUR) in 74 (30.0%), multicystic dysplastic kidney (MCDK) in 31 (12.6%), duplex collecting system in 28 (11.3%), and posterior urethral valves (PUV) in 25 (10.1%). In the UPJO subgroup, 67 of 89 patients (75.3%) demonstrated moderate to severe hydronephrosis (SFU grades III-IV) on initial postnatal ultrasound. Differential renal function below 40% on MAG3 renography was documented in 48 of 89 UPJO cases (53.9%), constituting the primary operative indication. Pyeloplasty was performed in 52 patients (58.4% of the UPJO subgroup) at a median age of 7.3 months (IQR: 5.1-11.4 months). Postoperative MAG3 reassessment at 12 months confirmed differential function recovery to ≥ 40% in 44 of 52 operated patients (84.6%). Among 74 VUR patients, VCUG grading revealed: grade I-II in 22 patients (29.7%), grade III in 28 (37.8%), grade IV in 17 (23.0%), and grade V in 7 (9.5%). DMSA scintigraphy identified cortical defects in 41 of 74 patients (55.4%), including 29 of 31 with grades IV-V (93.5%) and 12 of 43 with grade III (27.9%). Antibiotic prophylaxis was administered to 68 patients; breakthrough febrile infections occurred in 19 (27.9%). Endoscopic subureteral injection was performed in 33 cases; reflux resolution at 12 months was confirmed in 24 (72.7%). Spontaneous resolution occurred in 14 of 22 grade I-II patients (63.6%) over 24 months of surveillance.

In the MCDK cohort (n = 31), ultrasonographic involution was confirmed in 18 patients (58.1%) by 36 months. Compensatory contralateral hypertrophy was present in all 31 patients (100%), with mean contralateral renal length exceeding age-matched normative values by 14.6% ± 3.2%. PUV was diagnosed at a median age of 3.1 months (range: 0.2-14.0 months); median presenting serum creatinine was 94.7 ± 42.3 µmol/L. Primary valve ablation was completed in all 25 patients; 6 of 25 (24.0%) progressed to CKD stage III or beyond at final follow-up. Prenatally diagnosed patients underwent definitive intervention at a mean age of 5.8 ± 3.2 months versus 13.4 ± 5.7 months in the postnatally identified group ($p < 0.001$). Surgical complication rates were 11.2% versus 18.3%, respectively ($p = 0.031$), representing a 38.8% relative risk reduction.

Discussion

The 38.8% reduction in surgical complications attributable to prenatal diagnosis is the most operationally relevant finding of this study. The mechanistic explanation is straightforward: earlier referral compresses the interval between anatomical deterioration and corrective intervention, limiting the degree of irreversible parenchymal change that accumulates during obstructive or reflux-mediated renal injury. The 7.6-month difference in median age at intervention between prenatally and postnatally identified patients is not a statistical abstraction-it represents a clinically meaningful window during which hydronephrotic renal parenchyma either retains or loses its capacity for functional recovery. The 84.6% rate of differential function recovery following pyeloplasty is broadly consistent with the 75-87% range reported in European multicenter series, affirming that the operative threshold of 40% differential function applied in this study is appropriately calibrated. Critically, this

finding also corroborates Dlin and Osmanov's (2012) longitudinal renographic data linking deferred pyeloplasty to inferior recovery, which in the present cohort translated directly into a measurable outcome disadvantage for children in whom intervention was delayed beyond 18 months. The 27.9% prevalence of cortical scarring in grade III VUR patients exceeds figures of 15-20% reported in Western multicenter trials. The most plausible explanation lies in the greater cumulative febrile infection burden prior to diagnosis in postnatally identified children: this cohort sustained a mean of 2.3 documented febrile infections before VUR was confirmed, against 0.6 in prenatally detected cases. This gap is consistent with the framework articulated by Ignatova and Veltishchev (1989), wherein the first febrile episode establishes the principal scarring insult. Reflux nephropathy, once initiated, does not reverse; its prevention is therefore entirely contingent on diagnosis preceding recurrent pyelonephritic injury.

The MCDK involution rate of 58.1% by 36 months falls within the published range of 47-67% and supports conservative surveillance as the initial management strategy for uncomplicated cases. However, compensatory hypertrophy in all 31 MCDK patients carries its own long-term implications: functionally solitary kidneys are associated with progressive hyperfiltration injury, hypertension, and proteinuria across the second and third decades of life-a trajectory that Shamsiev and Atakulov (2003) characterized in detail for the Central Asian pediatric population. The 24% CKD progression rate among PUV patients reflects the intrinsic renal developmental compromise that accompanies posterior urethral obstruction and is only partially modifiable by timely valve ablation. Several limitations require acknowledgment. The absence of a standardized national prenatal screening program introduced referral timing heterogeneity and ultrasound quality variability. Retrospective data retrieval for pre-2018 records introduced ascertainment bias of uncertain magnitude. The 24-month minimum follow-up captures short-term surgical outcomes adequately but is insufficient to assess ultimate renal functional trajectory, which typically manifests across the second decade. These constraints notwithstanding, the data provide a substantive argument for protocol-driven postnatal imaging pathways anchored to validated prenatal APD thresholds.

Structured antenatal ultrasonography combined with protocol-driven postnatal evaluation-incorporating ultrasound, VCUG, and radionuclide renography-reduces surgical complication rates and accelerates operative intervention to within the functionally recoverable window. The 38.8% complication reduction documented here supports mandatory integration of unified CAKUT screening pathways into pediatric urological practice, particularly within regional centers operating under subspecialty resource constraints.

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